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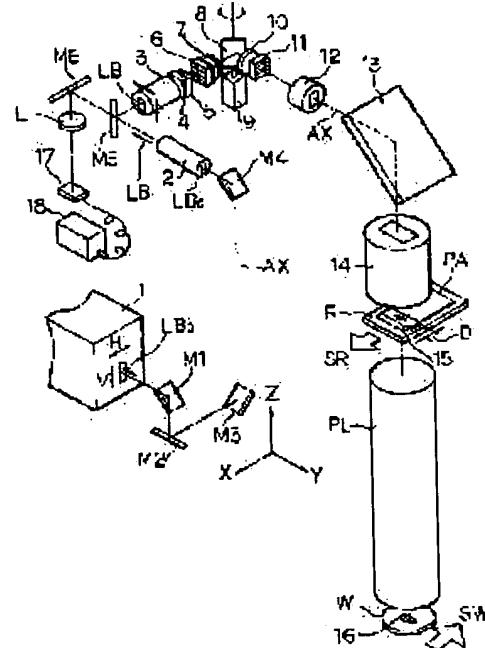
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(54) EXPOSURE DEVICE

(57)Abstract:

PURPOSE: To reduce illuminance irregularity due to speckle pattern when using light with a high spatial coherence as exposure light by the slit scan exposure system.

CONSTITUTION: A reticle R is scanned in a scanning direction SR for a lighting region 15. a wafer W is scanned in a scanning direction SW for an exposure region 16 which is conjugate to the lighting region 15, and then the pattern of the reticle R is exposed on the wafer W successively. The spatial coherence of laser beam LB0 discharged from an excimer laser light source 1 is high in horizontal direction (H direction), its horizontal direction is made to be conjugate to the scanning direction SR of the lighting region 15 and the direction where the spatial coherence higher becomes the scanning direction SR.



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CLAIMS

[Claim(s)]

[Claim 1] The light source which generates the illumination light which has predetermined spatial coherence, and the illumination-light study system which illuminates the lighting field of a predetermined configuration by said illumination light, In the aligner which has a relative scan means to synchronize and to scan the mask and the photosensitive substrate with which the pattern for an imprint was relatively formed to said lighting field, and exposes the pattern of said mask on said substrate serially The aligner characterized by making the high direction of the spatial coherence of said illumination light the same as that of the relative scanning direction of the lighting field of said predetermined configuration, and said mask.

[Claim 2] The source of pulsed light which generates the pulsed light which has predetermined spatial coherence, It has a relative scan means to synchronize and to scan the illumination-light study system which illuminates the lighting field of a predetermined configuration, the mask with which the pattern for an imprint was relatively formed to said lighting field, and a photosensitive substrate by said pulsed light. In the aligner which exposes the pattern of said mask on said substrate serially It responds to the relative scan speed of the lighting field of said predetermined configuration, and said mask, and the pitch of said relative scanning direction of the speckle pattern of said pulsed light in said lighting field. The aligner characterized by establishing a phase adjustable means to change the phase of the speckle pattern of said pulsed light in said lighting field for said every pulsed light.

[Claim 3] The aligner according to claim 2 characterized by establishing a spatial coherence detection means to detect the spatial coherence of said pulsed light, and the control means which controls actuation of said phase adjustable means according to the spatial coherence of said this detected pulsed light.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] By illuminating a rectangle or the lighting field of circular ** for example, with exposure light, and scanning a mask and a sensitization substrate synchronously to the lighting field, about the so-called aligner of the slit scan exposure method which exposes the pattern on a mask on a sensitization substrate serially, this invention is applied, when using a high light of especially spatial coherence as an exposure light, and it is suitable.

[0002]

[Description of the Prior Art] Conventionally, in case a semiconductor device, a liquid crystal display component, or the thin film magnetic head is manufactured using a photolithography technique, the projection aligner exposed on the substrates (a wafer or glass plate) with which the photo mask or the pattern of a reticle (it is hereafter named a "reticle" generically) was applied to the photoresist etc. through projection optics is used. In this projection aligner, in order to short-wavelength-ize exposure light and to raise resolution, excimer laser light like KrF excimer laser or ArF excimer laser or the laser beam of an ultraviolet area like the higher harmonic of argon laser is coming to be used as an exposure light.

[0003] However, spatial coherence (coherency) of a laser beam is high, and while passing an illumination-light study system, the interference fringe called a speckle pattern arises, and it has the problem that this becomes the illuminance unevenness on a reticle and a substrate. Then, in using a laser beam as an exposure light, in order to decrease the illuminance unevenness by the speckle pattern with the projection aligner of an one-shot exposure method like the conventional usual stepper, the oscillating mirror was arranged before the fly eye lens in an illumination-light study system (optical integrator). And he exposes changing the phase of the speckle pattern (interference fringe) produced on a reticle and a substrate, and was trying for the light exposure in the whole surface in each shot field on a substrate to become homogeneity among one exposure by scanning the laser beam which carries out incidence to the optical integrator by the oscillating mirror. In this case, the contrast of distribution of the light exposure on a substrate becomes min by shaking an oscillating mirror among one exposure, so that the phase of an interference fringe may do 2pi change of.

[0004]

[Problem(s) to be Solved by the Invention] The chip size of one piece of a semiconductor device tends to be enlarged recently, and large area-ization which exposes the pattern of a bigger area than that on a reticle on a substrate is called for in the projection aligner. In order to respond to large-area-izing of this transferred pattern, and a limit of the exposure field of projection optics, the rectangle and the projection aligner of the so-called slit scan exposure method which exposes the pattern on a reticle on a substrate serially circular or by scanning a reticle and a photosensitive substrate synchronously to lighting fields (this being called "slit-like lighting field"), such as six square shapes, are developed. To use a high light of spatial coherence like a laser beam as an exposure light also with the projection aligner of such a slit scan exposure method, it is necessary to reduce the illuminance unevenness by the speckle pattern.

[0005] However, by the slit scan exposure method, since the reticle and the substrate are scanned, the phase in which a SUPPEKURU pattern appears carries out time amount change. Therefore, the scanning direction of a reticle and a substrate poses a problem first. Next, when using together the oscillating mirror used at the time of an one-shot exposure method, it becomes a problem how an oscillating mirror is controlled according to the scan speed of a reticle and a substrate in the scanning direction list.

[0006] For example, pattern space PA of Reticle R is gradually scanned by the lighting field 51 relatively, drawing 7 (a) - (d) showing the condition of scanning Reticle R in the direction of X (scanning direction SR) to the slit-like lighting field 51, and applying it to the condition of drawing 7 (d) from the condition of

drawing 7 (a). Therefore, to the direction (non-scanning direction) perpendicular to the direction of X of Y, although the scan is substantially performed to the direction of X in pattern space PA of Reticle R, since it is a quiescent state, the effects of a speckle pattern differ in the scanning direction and the non-scanning direction.

[0007] This invention aims at making the illuminance unevenness by the speckle pattern as small as possible, when using a high light of spatial coherence as an exposure light with the aligner of a slit scan exposure method in view of this point.

[0008] [Means for Solving the Problem] As the 1st aligner by this invention is shown in drawing 1 and drawing 2 The light source which generates the illumination light (LB0) which has predetermined spatial coherence (1), The illumination-light study system which illuminates the lighting field (15) of a predetermined configuration by the illumination light (2-14), It has a relative scan means (32, 34, 35, RST, WST) to synchronize and to scan the mask (R) and the photosensitive substrate (W) with which the pattern for an imprint was relatively formed to the lighting field (15). In the aligner which exposes the pattern of a mask (R) on a substrate (W) serially, the high direction (direction H) of the spatial coherence of the illumination light (LB0) is made the same as that of the lighting field (15) of a predetermined configuration, and a relative scanning direction (direction SR) with a mask (R).

[0009] Moreover, as the 2nd aligner by this invention is shown in drawing 1 and drawing 2 The source of pulsed light which generates the pulsed light (LB0) which has predetermined spatial coherence (1), The illumination-light study system which illuminates the lighting field (15) of a predetermined configuration by the pulsed light (2-14), It has a relative scan means (32, 34, 35, RST, WST) to synchronize and to scan the mask (R) and the photosensitive substrate (W) with which the pattern for an imprint was relatively formed to the lighting field (15). In the aligner which exposes the pattern of a mask (R) on a substrate (W) serially to the lighting field (15) of a predetermined configuration, and a relative scan speed with a mask (R), According to the pitch of the relative scanning direction (direction SR) of the speckle pattern of the pulsed light in a lighting field (15), a phase adjustable means (8 9) to change the phase of the speckle pattern of the pulsed light in a lighting field (15) for every pulsed light of the is established.

[0010] In this case, it is desirable to establish a spatial coherence detection means (17 18) to detect the spatial coherence of that pulsed light, and the control means (32) which controls actuation of a phase adjustable means (8 9) according to the spatial coherence of that pulsed light detected in this way.

[0011] [Function] According to the 1st aligner of this this invention, the high direction of spatial coherence (coherent extent) was beforehand measured in the field perpendicular to the flux of light of the illumination light (LB0), and the high direction of the spatial coherence is doubled in the direction (the direction of SR) of a relative scan with a mask (R) in the lighting field (15) of a predetermined configuration. As it follows, for example, is shown in drawing 4 , the illuminance distribution of the scanning direction (the direction of SR) of the speckle pattern by the illumination light formed on a lighting field (15) is changed with the comparatively large amplitude in a predetermined pitch like a distribution curve 40. Moreover, the illumination distribution of the non-scanning direction (the direction of Y) of the speckle pattern on the lighting field (15) is comparatively flat like a distribution curve 41. In this case, in a scanning direction, since the illumination distribution of each point on a mask (R) becomes being the same as that of the case where changed like a distribution curve 40, respectively and it scans by the oscillating mirror substantially, there is little illuminance unevenness. Moreover, in a non-scanning direction, from the first, since there is little illuminance unevenness, its illuminance unevenness decreases all over a mask (R) and a substrate (W).

[0012] Moreover, according to the 2nd aligner of this invention, pulsed light is used as illumination light. Since it is not easy to erase the chromatic aberration in optical system when pulsed light is the excimer laser light (wavelength is 248nm) of for example, a far-ultraviolet region, in the source of pulsed light (1), the pulsed light which narrow-band-ized spectral line width is generated by using a diffraction grating, a slit, etc. Therefore, in drawing 1 , although, as for the pulsed light (LB0) injected from the light source (1), beam width has become [spatial coherence] high narrowly horizontally (the direction of H), perpendicularly (the direction of V), beam width has become [spatial coherence] low widely. Therefore, in this invention, the horizontal direction of the pulsed light (LB0) injected from the light source (1) is set as the scanning direction of the lighting field (15) of the shape of a slit on a mask (R).

[0013] In this case, generally, since it is smaller than the ratio of the width of face of the scanning direction of the lighting field (15) of the shape of a usual slit, and the width of face of a non-scanning direction, the ratio of width of face and vertical width of face with that horizontal pulsed light (LB0) needs to expand the

horizontal width of face of that pulsed light (LB0) using the cylindrical lenses 38 and 39 of two sheets as shown in drawing 3. the flare angle of the pulsed light (LB0) which carries out incidence at this time -- the focal distance of the cylindrical lens 38 of theta 1 and the preceding paragraph -- the focal distance of the cylindrical lens 39 of f1 and the latter part -- f2 ** -- flare angle theta 2 of the pulsed light (LB) which will be injected from a cylindrical lens 39 if it carries out It is as follows.

[0014] $\theta_2 = (f_1 / f_2) \theta_1$ (1)

Therefore, it is $f_1 < f_2$ in order to extend horizontal beam width. Flare angle theta 2 of the pulsed light (LB) which will be been as follows and injected if it carries out It becomes small.

$\theta_1 > \theta_2$ (2)

Therefore, if beam width is extended horizontally, as shown in drawing 4, the spatial coherence in the scanning direction (the direction of SR) of a lighting field (15) will become still higher. Therefore, the high speckle pattern of contrast is formed in a scanning direction. On the other hand, since the contrast of the speckle pattern of a non-scanning direction is low, there is little illuminance unevenness in a non-scanning direction.

[0015] The illumination distribution of the scanning direction of the lighting field (15) becomes like the distribution curve 40 of drawing 5 (a). If the scanning direction of a mask and a substrate is chosen in this direction, since it will become **** of the wave of various phases like drawing 5 (b) by the phase shift by scan, it counts upon mitigation of a speckle according to a superimpose effect. When not performing a certain control, however, depending on a scan speed The timing of pulse luminescence and the phase of a speckle pattern become a form mostly in agreement. At a certain irradiating point on a mask (R) For example, exposure is performed in order of the locations 40C and 40F of drawing 5 (a), and --, at another irradiating point, exposure is performed in order of locations 40B and 40E and --, a superimpose effect cannot be expected, and illuminance unevenness may not be mitigated. In order to avoid this, when it is the scan speed to which pulse luminescence is performed, an oscillating mirror is made to scan, and when emitting light by location 40F and emitting light by deltaA and location 40I, scan control to which the strike slip only of the deltaB is carried out is carried out in the locations 40C, 40F, and 40I of drawing 5 (a).

[0016] Thereby, since each irradiating point on a mask (R) is exposed with an illuminance with a SUPPEKURU pattern of a phase which is equally divided according to a pulse number and is different called the distribution curves 40, 42, and 43 of drawing 5 (b), addition light exposure is equalized and the illuminance unevenness in the scanning direction on a mask (R) is reduced. Namely, n and m are made into an integer in the irradiating point of the arbitration on a mask (R). So that the phase of the scanning direction on a distribution curve 40 may become 0, $2\pi m + (2\pi/n)$, $4\pi m + (4\pi/n)$, $6\pi m + (6\pi/n)$, ..., $2(n-1)\pi m + (n-1)\pi/n$, and ... for every pulse luminescence The illuminance unevenness of a scanning direction is reduced by controlling actuation of a phase adjustable means (8 9).

[0017] Moreover, a spatial coherence detection means to detect the spatial coherence of the pulsed light (17 18), thus, when the control means (32) which controls actuation of a phase adjustable means (8 9) according to the spatial coherence of the detected pulsed light is established Actuation of a phase adjustable means (8 9) is controlled so that the illuminance unevenness resulting from the speckle pattern on a mask (R) and a substrate (W) becomes min according to the detected spatial coherence.

[0018]

[Example] Hereafter, with reference to a drawing, it explains per example of the aligner by this invention. This example applies this invention to the projection aligner of the slit scan exposure method which used the laser light source of a pulse oscillation mold as the light source of exposure light. Drawing 1 is the laser beam LB0 of a far-ultraviolet region (wavelength is 248nm) which showed the optical system of the projection aligner of this example, and was injected from the excimer laser 1 in this drawing 1. Incidence is carried out to the beam plastic surgery optical system 2 which contains a cylindrical lens through the reflective mirrors M1, M2, M3, and M4 for ultraviolet. Laser beam LB0 injected from the excimer laser 1 Horizontal (the direction of H) width of face is a long and slender rectangle quite narrower than vertical (the direction of V) width of face, and a cross-section configuration is a laser beam LB0 at the beam plastic surgery optical system 2. Horizontal width of face is expanded and the laser beam LB of the cross-section configuration of the almost same aspect ratio as the aspect ratio of the lighting field 15 of the shape of a below-mentioned slit is injected.

[0019] Drawing 3 is the laser beam LB0 which carries out incidence as the configuration of the beam plastic surgery optical system 2 is shown and it is shown in this drawing 3. Focal distance f1 It passes through a cylindrical lens 38 and the cylindrical lens 39 of a focal distance f2 ($f_2 > f_1$), and the horizontal width of face of a cross-section configuration is f_2/f_1 . It is expanded twice. Laser beam LB0 which carries out

incidence It is a flare angle theta 1 Flare angle theta 2 of the laser beam LB which will be injected if it carries out Flare angle theta 1 It is decreasing to f_1/f_2 . The spatial coherence of the horizontal direction (the direction of H) of the laser beam LB injected since the spatial coherence of the flux of light is generally so high that a flare angle is small is the laser beam LB0 which carries out incidence. It is raised.

[0020] The laser beam LB injected by drawing 1 from return and the beam plastic surgery optical system 2 is bent by the reflective mirror M5 for ultraviolet, and carries out incidence to a beam expander (or zoom lens) 3, and a cross-section configuration is expanded even to a predetermined cross-section dimension.

Incidence of the parallel laser beam LB injected from the beam expander 3 is carried out to the Xtal prism 4 as a polarization means, and it is divided into two polarization components which intersect perpendicularly. Thus, incidence of the two separated polarization components is carried out to the quartz-glass prism 5 for optical-path amendment, and the travelling direction of a beam is amended. Then, the laser beam of two polarization components is bent by the oscillating mirror 8 through the 1st step of the fly eye lens 6 and a relay lens 7. With a driving gear 9, the oscillating mirror 8 scans a laser beam by the suitable control approach by include-angle within the limits predetermined [on a horizontal plane].

[0021] The laser beam scanned by the oscillating mirror 8 carries out incidence to the 2nd step of fly eye lens 11 through a relay lens 10, image formation of much 3rd light sources (spot light) is carried out to the focal plane by the side of the injection, and it is further condensed with a condenser lens 12, and the laser beam from the 3rd light source of these large number bends by the mirror 13, and carries out incidence to ***** and the Maine condenser lens 14. The width of face of the direction of a shorter side on Reticle R carries out weight of the laser beam from much 3rd light sources to the lighting field 15 of the rectangle of D, and it is irradiated by the Maine condenser lens 14. Image formation projection of the pattern image in the lighting field 15 is carried out into the exposure field 16 of the rectangle on Wafer W through projection optics PL.

[0022] In this case, the Z-axis is taken in parallel with the optical axis of projection optics PL, and the X-axis within XY flat surface perpendicular to that optical axis is taken in the direction of a shorter side of the rectangular lighting field 15. And it synchronizes with scanning Reticle R at a rate V in the direction of X (letting this be "a scanning direction SR") to the lighting field 15 in this example, using the projection scale factor of projection optics PL as beta. By scanning Wafer W by rate beta-V in the direction of -X (letting this be "a scanning direction SW"), projection exposure of the circuit pattern image in pattern space PA of Reticle R is serially carried out to the shot field of Wafer W.

[0023] In drawing 1 , in order to investigate the spatial coherence of excimer laser light, install a condenser lens L1 behind the reflective mirror M5 for ultraviolet, a backside [a condenser lens L1] focal location is made to condense the leakage light in the reflective mirror M5 for ultraviolet, and the leakage light distributed two-dimensional with the two-dimensional image sensor 17 which consists of CCD installed in the focal location is received. And the angle of divergence of a laser beam was measured by processing the image pick-up signal from the two-dimensional image sensor 17 by the image-processing system 18. Since the angle of divergence of a laser beam has the relation of an inverse proportion to spatial coherence, it can compute the spatial coherence of the scanning direction SR on the lighting field 15, and a non-scanning direction by the measured angle of divergence.

[0024] Drawing 2 shows the control system of the projection aligner of drawing 1 , and sets it to this drawing 2 . In an excimer laser 1 The electrode the gas used as the medium of laser oscillation, and for oscillation triggers The prism 24 for the enclosed laser tube 21, the front mirror 22 with the predetermined reflection factor (less than 100%) which constitutes a resonator, the rear mirror 23 of the resonator, the opening plate 29 for wavelength selections, wavelength selection, and the formation of a wavelength narrow band, and reflective mold diffraction-grating 25 grade It is prepared as an optical element. Furthermore, in order [of the oscillation control section 26 for making it oscillate by impressing the high voltage to the electrode in the laser tube 21, and the laser beam oscillated] to always make wavelength regularity absolutely, the mechanical-component 28 grade for adjusting the inclination of the wavelength adjustment mechanical component 27 which adjusts the tilt angle of a diffraction grating 25, and the rear mirror 23 is prepared in the excimer laser 1.

[0025] Moreover, a part of laser beam injected from the front mirror 22 is led to the wavelength detectors (spectroscopic etc.) 3 through a beam splitter 30, and the wavelength which detected and detected the wavelength of a laser beam with the wavelength detector 31 is transmitted to the wavelength adjustment mechanical component 27. The wavelength adjustment mechanical component 27 changes the tilt angle of a diffraction grating 25 so that a difference with the absolute wavelength defined beforehand may come in specification according to the wavelength detected with the wavelength detector 31. Moreover, the signal

(signal according to the magnitude of the beam spot specifically made on the two-dimensional image sensor 17) according to the beam angle of divergence which processes the image pick-up signal from the two-dimensional image sensor 17 by the image-processing system 18, and is detected is sent also to the main control unit 32 which controls actuation of the whole equipment while it is fed back to the mechanical component 28 of the rear mirror 23 of an excimer laser 1. A mechanical component 28 changes the tilt angle of the rear mirror 23, when the value of the angle of divergence of the beam surveyed to the value defined beforehand has separated more than tolerance.

[0026] Moreover, positioning and a scan of the reticle R of drawing 1 are performed by the reticle stage RST of drawing 2, and positioning and a scan of Wafer W are performed by the wafer stage WST of drawing 2. A reticle stage RST scans Reticle R, in order to change the exposure range of Reticle R on which the pattern of one chip was drawn one by one. the wafer stage WST has the function to move Wafer W by the step-and-repeat method, and the function which scans Wafer W synchronizing with the scan of Reticle R according to the exposure range of Reticle R in the direction of X, and the direction of Y so that two or more shot fields on Wafer W may be alike, respectively, it may receive and the pattern image of Reticle R may be exposed.

[0027] A main control unit 32 controls the oscillation of an excimer laser 1 through the oscillation control section 26, and controls actuation of the wafer stage WST and a reticle stage RST through the wafer stage control system 34 and the reticle stage control system 35, respectively. And a main control unit 32 controls amplitude, a period, etc. of vibration of the oscillating mirror 8 through a driving gear 9. Moreover, the displays (CRT display, meter, etc.) 33 grade as the keyboard 36, the coordinate input device (the so-called mouse) 37, and output unit as an input device is connected to the main control unit 32. A keyboard 36 and the coordinate input unit 37 are used [by the what pulse it exposes per one-shot field in exposure processing of a certain wafer, and] for [other than specifying beforehand] various sequence setup or a parameter setup.

[0028] Moreover, a main control unit 32 determines the oscillation frequency optimized so that a speckle pattern might be made the smallest without lowering reception and a throughput for the information on the beam angle of divergence of the laser beam from the excimer laser 1 under preliminary oscillation from the image-processing system 18, and the pulse number of the laser beam irradiated by one shot field on Wafer W, and emits a command to the oscillation control section 26. In parallel, while a main control unit 32 determines the period of vibration of the oscillating mirror 8, the amplitude, and a phase and emits a command to a driving gear 9, it determines the optimal scan speed as the reticle stage control system 35 and the wafer stage control system 34, and issues a command.

[0029] Next, it explains per configuration for reducing the illuminance unevenness on Reticle R and Wafer W by this example. First, laser beam LB0 injected from an excimer laser 1 in drawing 1 in this example Spatial coherence is high horizontally (the direction of H). Then, the laser beam LB0 An illumination-light study system is constituted so that the high direction of spatial coherence may turn into the direction SR of a shorter side of the lighting field 15, i.e., a scanning direction. Thereby, the speckle pattern of the laser beam formed on the lighting field 15 on Reticle R has the high contrast of a scanning direction SR, and the contrast of a non-scanning direction (the direction of Y) is low.

[0030] The periodic component corresponding to the array of the lens element of the fly eye lenses 6 and 11 is contained in the speckle pattern generated on the reticle R of drawing 1, and Wafer W, and the contrast of this interference pattern becomes high in the direction of X on Reticle R. In this example, in order to reduce the contrast of a speckle pattern, a laser beam LB is divided into the laser beam of two polarization components which makes a predetermined include angle with the Xtal prism 4 as a polarization means, and Reticle R is illuminated. Illuminance distribution [of the scanning direction (the direction of X) of the lighting field 15 by the laser beam of the 1st polarization component of the two polarization components] I (X) and a (relative value) are changing periodically in the predetermined pitch like the distribution curve 40 of drawing 6 (a). On the other hand, as a distribution curve 44 shows illuminance distribution I (X) by the laser beam of the 2nd polarization component, only the half-pitch has shifted in the direction of X to the distribution curve 40. Thereby, whole illumination distribution I (X) becomes the distribution curve 45 of drawing 6 (b), and the amplitude of fluctuation of illumination distribution is reduced.

[0031] Drawing 4 shows the illuminance distribution of the lighting field 15 on the reticle R of this example, and on Reticle R, as shown in drawing 4 (a), the lighting field 15 of the width of face D of a scanning direction SR (the direction of X) is formed. And illuminance distribution [of the direction of X of the lighting field 15] I (X) changes with the comparatively big amplitude in a predetermined pitch like the distribution curve 40 of drawing 4 (b), and its illuminance distribution [of the direction of Y of the lighting

field 15] I (Y) is almost flat like the distribution curve 41 of drawing 4 (c). Therefore, the illuminance unevenness in the direction of Y which is a non-scanning direction is small. Moreover, in this example, the illuminance unevenness in the direction of X is canceled by the scan of the reticle R to the lighting field 15, and the scan of the laser beam by the oscillating mirror 8 of drawing 1.

[0032] Drawing 5 (a) shows the distribution curve 40 corresponding to illumination distribution [of the scanning direction per 1 pulsed light in the lighting field 15 (the direction of X)] I (X), and X coordinate is [the field to D] the interior of the lighting field 15 of drawing 4 (a) from a zero. moreover -- if Reticle R is scanned in the direction of X to the lighting field 15 -- each irradiating point on Reticle R -- drawing 5 (a) -- (-- drawing 5 (b) -- the same --) -- it shall move along with the X-axis

[0033] When setting to n the need [that pulse luminescence is performed and the pitch of a distribution curve 40 is called for from the energy density and resist sensibility of PX and one pulse in this example] pulse number, by n pulse luminescence A scan speed from which 0, PX/n, 2 PX/n, ..., the distribution curve that has a peak in each location of PX/n (n-1) are acquired (0, PX/n, 2 PX/n, ..., the distribution curve that has a peak in order of PX/n (n-1) do not need to appear.) By n pulse luminescence, all the distribution curves that have a peak in each location should just be acquired. moreover, n -- enough -- being large -- a pitch PX -- n/2, n/3, and ... the distribution curve which has a peak in the location divided equally is just acquired. When in agreement with the rate (value $V=(D/n)$ f which broke the exposure field D by need pulse number n, and applied the oscillation frequency f of laser) determined beforehand, it is not necessary to make the oscillating mirror 8 of drawing 1 scan, and the illuminance unevenness on Reticle R and Wafer W is mitigated most efficiently.

[0034] For example, when a need pulse number is 3, Reticle R moves in the direction of X only D/3 for every pulse. Therefore, at a certain irradiating point on Reticle R (X= 0), as shown in drawing 5 (a), if exposure is performed in order and light exposure distribution of the direction of X is seen, since [of the locations 40A, 40E, and 40I of spacing D / 3, and --] it will become the superposition of the pulse of the distribution curves 40, 42, and 43 of drawing 5 (b), the quantity of light unevenness of addition light exposure becomes very small. The distance which Reticle R moves for every pulse is beforehand set as 1 for an integer of the width of face D of the scanning direction of the lighting field 15.

[0035] However, since the scan speed of Reticle R and Wafer W is determined like the after-mentioned by the proper light exposure on Wafer W etc., the aforementioned conditions may not necessarily be satisfied. In such a case, the oscillating mirror 8 of drawing 1 is scanned and 0, PX/n, 2 PX/n, ..., the distribution curve that has a peak in the location of PX/n (n-1) need to be made to be acquired.

[0036] When a need pulse number is 4 concretely, Reticle R moves in the direction of X only D/4 for every pulse. As shown in drawing 5 (a), therefore, at a certain irradiating point on Reticle R (X= 0) spacing -- D/4 of the locations 40A, 40D, 40G, and 40K -- exposure being performed in order of ... and at a certain another point and the point which separated only D/6 from the location of X= 0 Since exposure is performed in order of locations 40C, 40F, 40I, and 40L, distribution of the addition light exposure of the direction of X serves as superposition of a distribution curve 40, and mitigation of quantity of light unevenness is not carried out at all. Then, the oscillating mirror 8 is made to scan. For example, it becomes the superposition of the wave of four kinds of phases from which it differs like drawing 5 (c) at the time of PX/4 and location 40I at the time of exposure when only 3PX / 4 change a phase by the scan of the oscillating mirror 8 at the time of PX/2 and location 40L by location 40F, and illuminance unevenness becomes very small. By drawing 5 (c), distribution curves 46, 47, and 48 change a phase only for PX/4, PX/2, and 3PX / 4 by the oscillating mirror 8 from a distribution curve 40, respectively.

[0037] Next, it explains per scan speed of Reticle R and Wafer W. The scan speed of Wafer W is first determined by the proper light exposure (this becomes settled with the sensibility of the resist applied on Wafer W) given to Wafer W, and the amount of energy for every pulse. Since the amounts of energy emitted for every pulse differ in the case of the light source like an excimer laser 1, it dims in an illumination-light study system, and the amount of energy for every pulse is determined by increasing and exposing a pulse number so that dispersion in the light exposure given to Wafer W by the superimpose effect may decrease.

[0038] It is EP in the proper light exposure given to a wafer about E and the amount of energy for every pulse (the amount of average energies). If it carries out An exposure pulse number is E/EP. Since the scan lay length (namely, width of face of the scanning direction of the lighting field 15) of the range which is expressed and is illuminated at once on Reticle R is D, The movement magnitude of the reticle R for every pulse serves as D (EP/E), and when the oscillation frequency of an excimer laser 1 is f [Hz], the scan speed V of Reticle R is set as the value of a degree type.

[0039] V=(EP/E) f-D (3)

In addition, although the scan of the speckle pattern to the non-scanning direction (the direction of Y of drawing 4) of the lighting field 15 was omitted in the above-mentioned example, in order to mitigate the illuminance unevenness of a non-scanning direction more, it is desirable by shaking the oscillating mirror 8 perpendicularly in drawing 1 to scan a speckle pattern also to a non-scanning direction.

[0040] Moreover, in drawing 4 , in order to vibrate a speckle pattern to both a scanning direction SR (the direction of X), and a non-scanning direction (the direction of Y), a speckle pattern may be vibrated in the direction which crosses in the direction of X, and the direction of Y.

[0041] In addition, there is also the following technique in the approach a high direction and whose scanning direction spatial coherence makes correspond.

** If the reticle and the wafer are constituted from a body side of an aligner possible [a scan] in X and Y both directions, even if it is after connecting a body and a laser light source, coherence should just make a high direction the scanning direction. At this time, it is necessary to set up the configuration of a lighting field with a reticle blind so that this determined scanning direction may turn into the direction of a short hand of the lighting field on a reticle.

** What is necessary is for two or more mirrors just to adjust the high direction of the coherence of the laser beam in which the high direction of the spatial coherence of the laser beam from a laser light source carries out incidence to the illumination-light study system of an aligner so that it may be in agreement with the scanning direction. However, it may be necessary to adjust a fly eye lens etc. It is desirable to construct equipment in consideration of the high direction of coherence generally.

[0042] In addition, when using the laser beam which this invention is not limited to the above-mentioned example, for example, consists of a higher harmonic of an YAG laser as an exposure light, or when using continuation light like i line of a mercury lamp as an exposure light, of course, configurations various in the range which does not deviate from the summary of this invention can be taken.

[0043]

[Effect of the Invention] According to the 1st aligner of this invention, since the high direction of the contrast of the interference fringe of a SUPPEKURU pattern is mitigated by relative scan with a lighting field and a mask (substrate) in accordance with a scanning direction, the illuminance unevenness of the scanning direction has the advantage to which the illuminance unevenness by the speckle pattern becomes small.

[0044] Moreover, according to the 2nd aligner, since the phase of the speckle pattern of the pulsed light in a lighting field can be changed for every pulsed light according to the relative scan speed of a lighting field and a mask, and the pitch of the relative scanning direction of the speckle pattern of the pulsed light in the lighting field, there is an advantage which can make the illuminance unevenness by the speckle pattern small.

[0045] Moreover, especially when a spatial coherence detection means to detect the spatial coherence of pulsed light, and the control means which controls actuation of a phase adjustable means according to the spatial coherence of the pulsed light detected in this way are established, the illuminance unevenness by the speckle pattern can be made small.

[Translation done.]

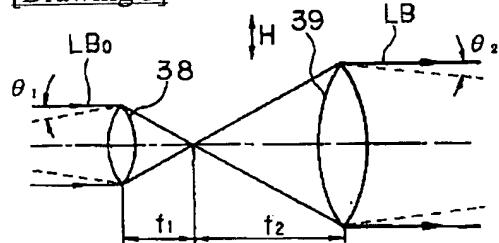
* NOTICES *

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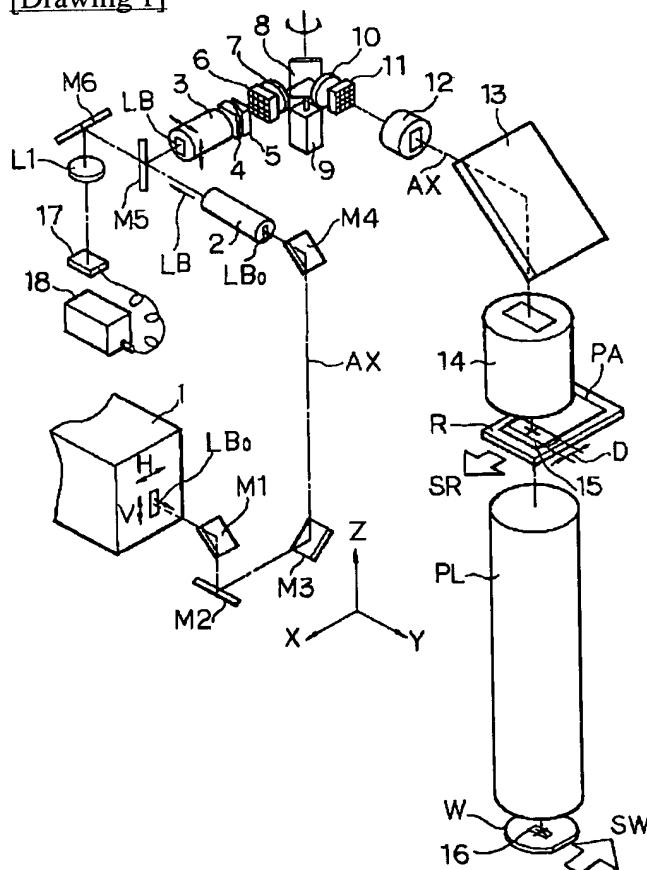
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DRAWINGS

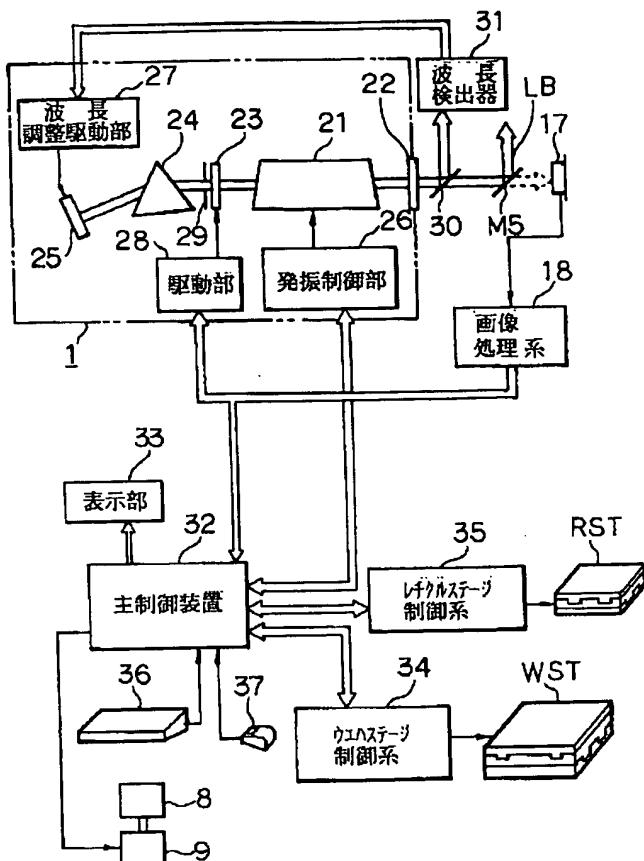
[Drawing 3]



[Drawing 1]

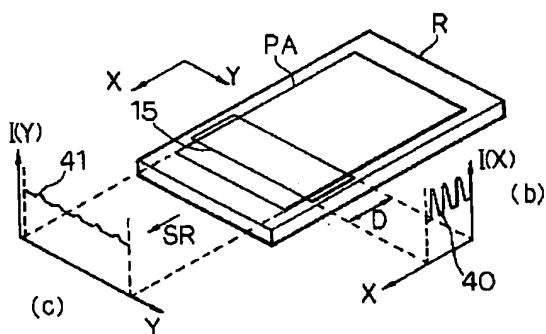


[Drawing 2]

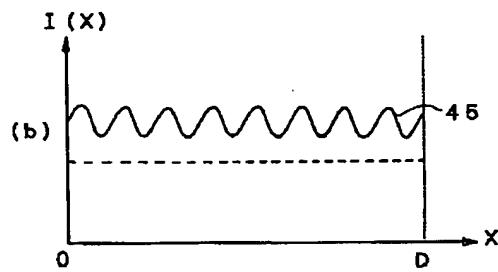
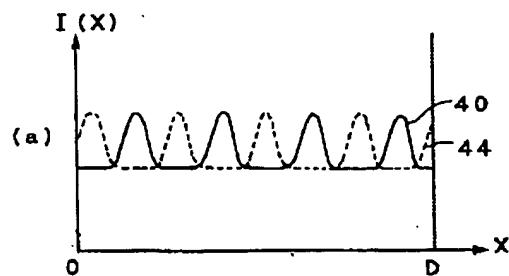


[Drawing 4]

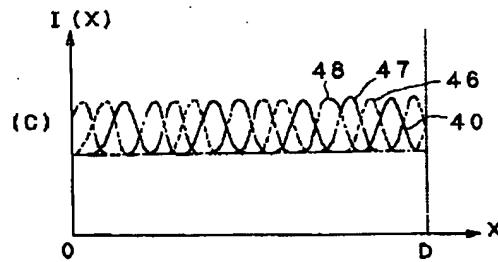
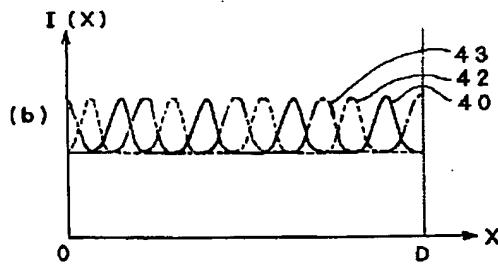
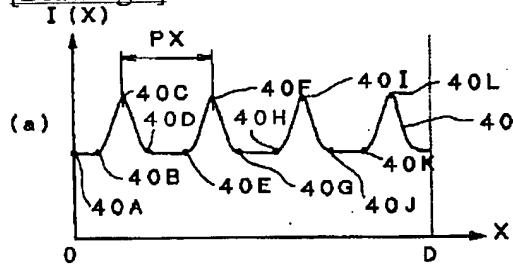
(a)



[Drawing 6]

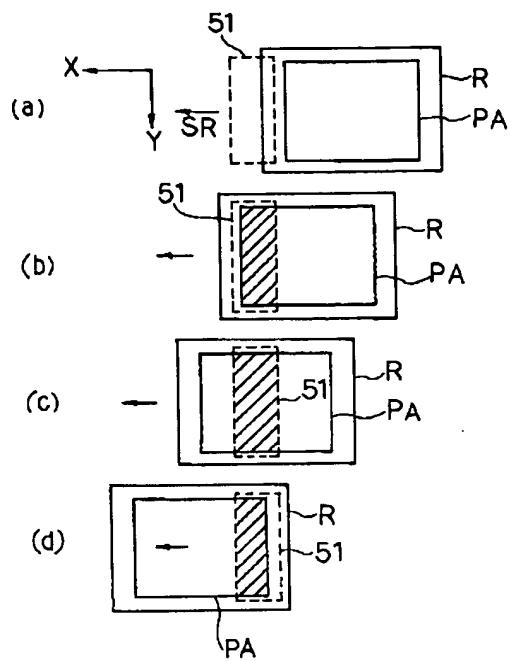


[Drawing 5]



[Drawing 7]

)



[Translation done.]

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CORRECTION OR AMENDMENT

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[Filing Date] May 31, Heisei 12 (2000. 5.31)

[Procedure amendment 1]

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[Item(s) to be Amended] The name of invention

[Method of Amendment] Modification

[Proposed Amendment]

[Title of the Invention] The exposure approach and equipment

[Procedure amendment 2]

[Document to be Amended] Specification

[Item(s) to be Amended] Claim

[Method of Amendment] Modification

[Proposed Amendment]

[Claim(s)]

[Claim 1] In the aligner which has the light source which generates the illumination light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined configuration by said illumination light, and a relative scan means to synchronize and to scan the mask and substrate with which the predetermined pattern was relatively formed to said lighting field, and carries out scan exposure of said substrate,

The aligner characterized by making the high direction of the spatial coherence of said illumination light the same as that of the relative scanning direction of the lighting field of said predetermined configuration, and said mask.

[Claim 2] The high direction of the spatial coherence of said illumination light is an aligner according to claim 1 characterized by the contrast of the speckle pattern formed in said lighting field being a high

direction.

[Claim 3] The aligner according to claim 1 or 2 characterized by having further the displacement means to which the variation rate of the speckle pattern of said illumination light formed in said lighting field is carried out in said lighting field.

[Claim 4] Said displacement means is an aligner according to claim 3 characterized by making the variation rate of said speckle pattern carry out towards said relative scan.

[Claim 5] Said displacement means is an aligner according to claim 3 or 4 characterized by making the variation rate of said speckle pattern carry out in the direction of said relative scan, and the crossing direction.

[Claim 6] The direction of said relative scan and the crossing direction are an aligner according to claim 5 characterized by the contrast of said speckle pattern being a low direction.

[Claim 7] Said light source is a source of pulsed light which carries out pulse luminescence of said illumination light,

Said displacement means is the aligner of claim 3-6 characterized by carrying out the variation rate of said speckle pattern synchronizing with said pulse oscillation given in any 1 term.

[Claim 8] In the aligner which has the source of pulsed light which generates the pulsed light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined configuration by said pulsed light, and a relative scan means to synchronize and to scan the mask and substrate with which the predetermined pattern was relatively formed to said lighting field, and carries out scan exposure of said substrate,

The aligner characterized by establishing a phase adjustable means to change the phase of the speckle pattern of said pulsed light in said lighting field for said every pulsed light, according to the relative scan speed of the lighting field of said predetermined configuration, and said mask, and the pitch of said relative scanning direction of the speckle pattern of said pulsed light in said lighting field.

[Claim 9] The aligner according to claim 8 characterized by establishing a spatial coherence detection means to detect the spatial coherence of said pulsed light, and the control means which controls actuation of said phase adjustable means according to the spatial coherence of said this detected pulsed light.

[Claim 10] In the aligner which has the light source which generates the illumination light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined configuration by said illumination light, and a relative scan means to synchronize and to scan the mask and substrate with which the predetermined pattern was relatively formed to said lighting field, and carries out scan exposure of said substrate,

The displacement means to which the variation rate of the speckle pattern of said illumination light formed in said lighting field is carried out in said lighting field,

The control means which controls said displacement means so that the effect of the speckle pattern formed in said lighting field is reduced, while said mask and said substrate are moving to said lighting field during said scan exposure,

The aligner characterized by preparation *****.

[Claim 11] Said control means is an aligner according to claim 10 characterized by controlling said displacement means so that said speckle pattern displaces to said relative scanning direction.

[Claim 12] Said control means is an aligner according to claim 11 characterized by controlling said displacement means according to the relative scan speed of said lighting field and said mask.

[Claim 13] Said control means is an aligner according to claim 11 or 12 characterized by controlling said displacement means according to the illumination distribution of said speckle pattern.

[Claim 14] Said control means is the aligner of claim 10-13 characterized by controlling said displacement means so that said speckle pattern displaces in the direction of said relative scan, and the crossing direction given in any 1 term.

[Claim 15] Said light source is a source of pulsed light which carries out pulse luminescence of said illumination light,

Said displacement means is the aligner of claim 10-14 characterized by carrying out the variation rate of said speckle pattern synchronizing with said pulse oscillation given in any 1 term.

[Claim 16] It has further a detection means to detect the spatial coherence of said illumination light, Said control means is the aligner of claim 10-15 characterized by controlling said displacement means according to the spatial coherence detected with said detection means given in any 1 term.

[Claim 17] In the aligner which has the light source which generates the illumination light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined

configuration by said illumination light, and a relative scan means to synchronize and to scan the mask and substrate with which the predetermined pattern was relatively formed to said lighting field, and carries out scan exposure of said substrate,

A measurement means to measure the information on the angle of divergence of said illumination light, The control means which controls the exposure conditions of said substrate based on the information on the measured this angle of divergence,

The aligner characterized by preparation *****.

[Claim 18] In the aligner which has the light source which generates the illumination light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined configuration by the illumination light, and a relative scan means to synchronize and to scan the mask and substrate with which the predetermined pattern was relatively formed to said lighting field, and carries out scan exposure of said substrate,

Said illumination-light study system has a polarization means to divide the illumination light from said light source into the 1st illumination light of the 1st polarization component, and the 2nd illumination light of the 2nd polarization component,

Said 1st illumination light and said 2nd illumination light are an aligner characterized by shifting the illumination distribution on said mask to said relative scanning direction mutually.

[Claim 19] In the exposure approach which carries out scan exposure of said substrate by scanning synchronously the mask and substrate with which the predetermined pattern was relatively formed to said lighting field while illuminating the lighting field of a predetermined configuration by the illumination light which has spatial coherence,

The exposure approach characterized by making the same as that of the relative scanning direction of the lighting field of said predetermined configuration, and said mask the high direction of the contrast of the speckle pattern formed in said lighting field.

[Claim 20] In the exposure approach which carries out scan exposure of said substrate by scanning synchronously the mask and substrate with which the predetermined pattern was relatively formed to said lighting field while illuminating a lighting field by the illumination light which has spatial coherence, Said illumination light is discharged from the light source with the cross-section configuration which has a longitudinal direction and the direction of a short hand,

The exposure approach that the direction of a short hand of the cross-section configuration of said illumination light is characterized by making it in agreement with the relative scanning direction of said lighting field and said mask.

[Claim 21] In the exposure approach which carries out scan exposure of said substrate by scanning synchronously the mask and substrate with which the predetermined pattern was relatively formed to said lighting field while illuminating the lighting field of a predetermined configuration by the illumination light which has spatial coherence,

The exposure approach characterized by carrying out the variation rate of said speckle pattern in said lighting field so that the effect of the speckle pattern formed in said lighting field may become small, while said mask and said substrate are moving to said lighting field during said scan exposure.

[Procedure amendment 3]

[Document to be Amended] Specification

[Item(s) to be Amended] 0001

[Method of Amendment] Modification

[Proposed Amendment]

[0001]

[Industrial Application] By illuminating a rectangle or the lighting field of circular ** for example, with exposure light, and scanning a mask and a sensitization substrate synchronously to the lighting field, about the so-called exposure approach of a slit scan exposure method and aligner which expose the pattern on a mask on a sensitization substrate serially, this invention is applied, when using a high light of especially spatial coherence as an exposure light, and it is suitable.

[Procedure amendment 4]

[Document to be Amended] Specification

[Item(s) to be Amended] 0007

[Method of Amendment] Modification

[Proposed Amendment]

[0007] This invention aims at making the illuminance unevenness by the speckle pattern as small as

possible, when using a high light of spatial coherence as an exposure light with the exposure approach of a slit scan exposure method, and an aligner in view of this point.

[Procedure amendment 5]

[Document to be Amended] Specification

[Item(s) to be Amended] 0008

[Method of Amendment] Modification

[Proposed Amendment]

[0008]

[Means for Solving the Problem] As the 1st aligner by this invention is shown in drawing 1 and drawing 2 The light source which generates the illumination light (LB0) which has spatial coherence (1), The illumination-light study system which illuminates the lighting field (15) of a predetermined configuration by the illumination light (2-14), It has a relative scan means (32, 34, 35, RST, WST) to synchronize and to scan the mask (R) and substrate (W) with which the predetermined pattern was relatively formed to the lighting field (15). In the aligner which carries out scan exposure of the substrate (W), the high direction (direction H) of the spatial coherence of the illumination light (LB0) is made the same as that of the lighting field (15) of a predetermined configuration, and a relative scanning direction (direction SR) with a mask (R).

[Procedure amendment 6]

[Document to be Amended] Specification

[Item(s) to be Amended] 0009

[Method of Amendment] Modification

[Proposed Amendment]

[0009] Moreover, as the 2nd aligner by this invention is shown in drawing 1 and drawing 2 The source of pulsed light which generates the pulsed light (LB0) which has spatial coherence (1), The illumination-light study system which illuminates the lighting field (15) of a predetermined configuration by the pulsed light (2-14), It has a relative scan means (32, 34, 35, RST, WST) to synchronize and to scan the mask (R) and substrate (W) with which the predetermined pattern was relatively formed to the lighting field (15). In the aligner which carries out scan exposure of the substrate (W) The lighting field (15) of a predetermined configuration, and a relative scan speed with a mask (R), According to the pitch of the relative scanning direction (direction SR) of the speckle pattern of the pulsed light in a lighting field (15), a phase adjustable means (8 9) to change the phase of the speckle pattern of the pulsed light in a lighting field (15) for every pulsed light of the is established.

[Procedure amendment 7]

[Document to be Amended] Specification

[Item(s) to be Amended] 0010

[Method of Amendment] Modification

[Proposed Amendment]

[0010] In this case, it is desirable to establish a spatial coherence detection means (17 18) to detect the spatial coherence of that pulsed light, and the control means (32) which controls actuation of a phase adjustable means (8 9) according to the spatial coherence of that pulsed light detected in this way. Next, the 3rd aligner of this invention has the light source which generates the illumination light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined configuration by the illumination light, and a relative scan means synchronize and scan the mask and the substrate with which the predetermined pattern was relatively formed to the lighting field, and is characterized by to provide the following in the aligner which carries out scan exposure of the substrate. The displacement means to which the variation rate of the speckle pattern of the illumination light formed in the lighting field is carried out in the lighting field The control means which controls the displacement means so that the effect of the speckle pattern formed in the lighting field is reduced, while the mask and its substrate are moving to the lighting field during the scan exposure Moreover, the 4th aligner of this invention has the light source which generates the illumination light which has spatial coherence, the illumination-light study system which illuminates the lighting field of a predetermined configuration by the illumination light, and a relative scan means synchronize and scan the mask and the substrate with which the predetermined pattern was relatively formed to the lighting field, and is characterized by to provide the following in the aligner which carries out scan exposure of the substrate. A measurement means to measure the information on the angle of divergence of the illumination light The control means which controls the exposure conditions of that substrate based on the information on this measured angle of divergence Moreover, the light source in which the 5th aligner by this invention generates the illumination light which has spatial coherence, In the

[Procedure amendment 8]

[Document to be Amended] Specification

[Item(s) to be Amended] 0016

[Method of Amendment] Modification

[Proposed Amendment]

[0016] Thereby, since each irradiating point on a mask (R) is exposed with an illuminance with a speckle pattern of a phase which is equally divided according to a pulse number and is different called the distribution curves 40, 42, and 43 of drawing 5 (b), addition light exposure is equalized and the illuminance unevenness in the scanning direction on a mask (R) is reduced. Namely, n and m are made into an integer in the irradiating point of the arbitration on a mask (R). So that the phase of the scanning direction on a distribution curve 40 may become 0, $2\pi m + (2\pi/n)$, $4\pi m + (4\pi/n)$, $6\pi m + (6\pi/n)$, ..., $2(n-1)\pi m + 2(n-1)\pi/n$, and ... for every pulse luminescence. The illuminance unevenness of a scanning direction is reduced by controlling actuation of a phase adjustable means (8 9).

[Procedure amendment 9]

[Document to be Amended] Specification

[Item(s) to be Amended] 0018

[Method of Amendment] Modification

[Proposed Amendment]

[0018]

[Example] Hereafter, with reference to a drawing, it explains per example of this invention. This example applies this invention to the projection aligner of the slit scan exposure method which used the laser light source of a pulse oscillation mold as the light source of exposure light. Drawing 1 is the laser beam LB0 of a far-ultraviolet region (wavelength is 248nm) which showed the optical system of the projection aligner of this example, and was injected from the excimer laser 1 in this drawing 1. Incidence is carried out to the beam plastic surgery optical system 2 which contains a cylindrical lens through the reflective mirrors M1, M2, M3, and M4 for ultraviolet. Laser beam LB0 injected from the excimer laser 1. Horizontal (the direction of H) width of face is a long and slender rectangle quite narrower than vertical (the direction of V) width of face, and a cross-section configuration is a laser beam LB0 at the beam plastic surgery optical system 2. Horizontal width of face is expanded and the laser beam LB of the cross-section configuration of the almost same aspect ratio as the aspect ratio of the lighting field 15 of the shape of a below-mentioned slit is

injected.

[Procedure amendment 10]

[Document to be Amended] Specification

[Item(s) to be Amended] 0019

[Method of Amendment] Modification

[Proposed Amendment]

[0019] Drawing 3 is the laser beam LB0 which carries out incidence as the configuration of the beam plastic surgery optical system 2 is shown and it is shown in this drawing 3. Focal distance f1 It passes through a cylindrical lens 38 and the cylindrical lens 39 of a focal distance f2 ($f2 > f1$), and the horizontal width of face of a cross-section configuration is $f2/f1$. It is expanded twice. Laser beam LB0 which carries out incidence It is a flare angle theta 1 Flare angle theta 2 of the laser beam LB which will be injected if it carries out Flare angle theta 1 $f1/f2$ It is decreasing. The spatial coherence of the horizontal direction (the direction of H) of the laser beam LB injected since the spatial coherence of the flux of light is generally so high that a flare angle is small is the laser beam LB0 which carries out incidence. It is raised.

[Procedure amendment 11]

[Document to be Amended] Specification

[Item(s) to be Amended] 0025

[Method of Amendment] Modification

[Proposed Amendment]

[0025] Moreover, a part of laser beam injected from the front mirror 22 is led to the wavelength detectors (spectroscope etc.) 31 through a beam splitter 30, and the wavelength which detected and detected the wavelength of a laser beam with the wavelength detector 31 is transmitted to the wavelength adjustment mechanical component 27. The wavelength adjustment mechanical component 27 changes the tilt angle of a diffraction grating 25 so that a difference with the absolute wavelength defined beforehand may come in specification according to the wavelength detected with the wavelength detector 31. Moreover, the signal (signal according to the magnitude of the beam spot specifically made on the two-dimensional image sensor 17) according to the beam angle of divergence which processes the image pick-up signal from the two-dimensional image sensor 17 by the image-processing system 18, and is detected is sent also to the main control unit 32 which controls actuation of the whole equipment while it is fed back to the mechanical component 28 of the rear mirror 23 of an excimer laser 1. A mechanical component 28 changes the tilt angle of the rear mirror 23, when the value of the angle of divergence of the beam surveyed to the value defined beforehand has separated more than tolerance.

[Procedure amendment 12]

[Document to be Amended] Specification

[Item(s) to be Amended] 0043

[Method of Amendment] Modification

[Proposed Amendment]

[0043]

[Effect of the Invention] According to this invention, since the high direction of the contrast of the interference fringe of a speckle pattern is mitigated by relative scan with a lighting field and a mask (substrate) in accordance with a scanning direction, the illuminance unevenness of the scanning direction has the advantage to which the illuminance unevenness by the speckle pattern becomes small.

[Procedure amendment 13]

[Document to be Amended] Specification

[Item(s) to be Amended] 0044

[Method of Amendment] Modification

[Proposed Amendment]

[0044] Moreover, since he is trying to displace a speckle pattern in a lighting field according to this invention while carrying out the relative scan of a mask and the substrate to the lighting field, the mitigation and the interval by relative scan of a lighting field and a mask (substrate) make very small effect of the illuminance unevenness by the speckle pattern, and can carry out the thing of it.

[Procedure amendment 14]

[Document to be Amended] Specification

[Item(s) to be Amended] 0045

[Method of Amendment] Modification

[Proposed Amendment]

[0045] Especially, according to the relative scan speed of a lighting field and a mask (substrate), and the pitch of the relative scanning direction of the speckle pattern of the pulsed light in the lighting field, the illuminance unevenness by the speckle pattern can be made smaller by changing the phase of the speckle pattern of the pulsed light in a lighting field for every pulsed light.

[Translation done.]

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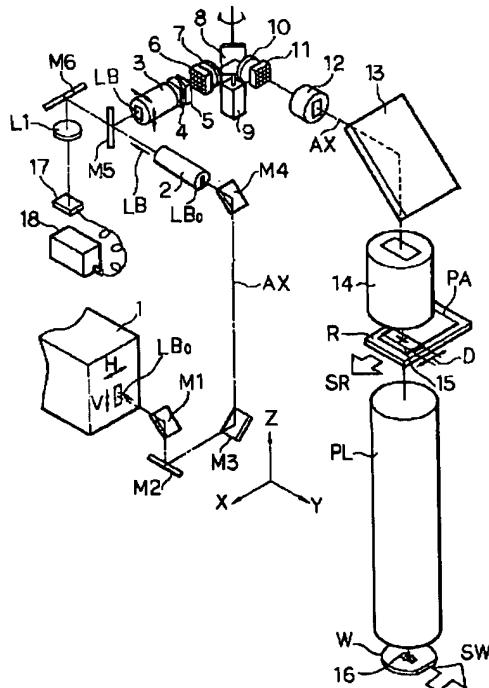
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(54)【発明の名称】 露光装置

(57)【要約】

【目的】 スリットスキャン露光方式で空間コヒーレンスの高い光を露光光として使用する場合に、スペックルパターンによる照度むらを小さくする。

【構成】 照明領域15に対してレチクルRを走査方向SRに走査し、照明領域15と共に露光領域16に対してウエハWを走査方向SWに走査し、レチクルRのパターンを逐次ウエハW上に露光する。エキシマレーザ光源1から射出されるレーザビームLB₀の空間コヒーレンスは水平方向(H方向)に高いため、その水平方向と照明領域15の走査方向SRとを共役にして、空間コヒーレンスの高い方を走査方向SRとする。



1

【特許請求の範囲】

【請求項1】 所定の空間コヒーレンスを有する照明光を発生する光源と、前記照明光で所定形状の照明領域を照明する照明光学系と、前記照明領域に対して相対的に転写用のパターンが形成されたマスク及び感光性の基板を同期して走査する相対走査手段とを有し、前記マスクのパターンを逐次前記基板上に露光する露光装置において、

前記照明光の空間コヒーレンスの高い方向を前記所定形状の照明領域と前記マスクとの相対的な走査方向と同じにしたことを特徴とする露光装置。

【請求項2】 所定の空間コヒーレンスを有するパルス光を発生するパルス光源と、前記パルス光で所定形状の照明領域を照明する照明光学系と、前記照明領域に対して相対的に転写用のパターンが形成されたマスク及び感光性の基板を同期して走査する相対走査手段とを有し、前記マスクのパターンを逐次前記基板上に露光する露光装置において、

前記所定形状の照明領域と前記マスクとの相対的な走査速度と、前記照明領域での前記パルス光のスペックルパターンの前記相対的な走査方向のピッチとに応じて、前記照明領域での前記パルス光のスペックルパターンの位相を前記パルス光毎に変化させる位相可変手段を設けたことを特徴とする露光装置。

【請求項3】 前記パルス光の空間コヒーレンスを検出する空間コヒーレンス検出手段と、該検出された前記パルス光の空間コヒーレンスに応じて前記位相可変手段の動作を制御する制御手段と、を設けたことを特徴とする請求項2記載の露光装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明は、例えば露光光で矩形又は円弧状等の照明領域を照明し、その照明領域に対してマスク及び感光基板を同期して走査することにより、マスク上のパターンを逐次感光基板上に露光する所謂スリットスキャン露光方式の露光装置に関し、特に空間コヒーレンスの高い光を露光光として用いる場合に適用して好適なものである。

【0002】

【従来の技術】 従来より、半導体素子、液晶表示素子又は薄膜磁気ヘッド等をフォトリソグラフィー技術を用いて製造する際に、フォトマスク又はレチクル（以下、「レチクル」と総称する）のパターンを投影光学系を介して、フォトレジスト等が塗布された基板（ウエハ又はガラスプレート等）上に露光する投影露光装置が使用されている。斯かる投影露光装置では、露光光を短波長化して解像度を向上させるために、KrFエキシマレーザ若しくはArFエキシマレーザのようなエキシマレーザ光、又はアルゴンレーザの高調波のような紫外域のレーザ光が露光光として使用されるようになって来ている。

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【0003】 ところが、レーザ光は空間コヒーレンス（可干渉性）が高く、照明光学系を通過する間にスペックルパターンと呼ばれる干渉縞が生じ、これがレチクル及び基板上での照度むらになるという問題がある。そこで、従来の通常のステッパーのような一括露光方式の投影露光装置で、レーザ光を露光光として使用する場合には、スペックルパターンによる照度むらを減少させるために、照明光学系中のフライアイレンズ（オプティカル・インテグレータ）の前に振動ミラーを配置していた。そして、1度の露光の間に、そのオプティカル・インテグレータに入射するレーザ光をその振動ミラーで走査することによって、レチクル及び基板上に生じるスペックルパターン（干渉縞）の位相を変えながら露光を行い、基板上の各ショット領域内の全面での露光量が均一になるようにしていた。この場合、一回の露光の間に、干渉縞の位相が 2π 変化するように振動ミラーを振ることにより、基板上の露光量の分布のコントラストが最小になる。

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【0004】

【発明が解決しようとする課題】 最近は、半導体素子の1個のチップサイズが大型化する傾向にあり、投影露光装置においては、レチクル上のより大きな面積のパターンを基板上に露光する大面積化が求められている。斯かる被転写パターンの大面積化及び投影光学系の露光フィールドの制限に応えるために、例えば矩形、円弧状又は6角形等の照明領域（これを「スリット状の照明領域」という）に対してレチクル及び感光性の基板を同期して走査することにより、レチクル上のパターンを逐次基板上に露光する所謂スリットスキャン露光方式の投影露光装置が開発されている。このようなスリットスキャン露光方式の投影露光装置でも、露光光としてレーザ光のような空間コヒーレンスの高い光を使用する場合には、スペックルパターンによる照度むらを低減させる必要がある。

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【0005】 しかしながら、スリットスキャン露光方式では、レチクル及び基板が走査されているためスペックルパターンの出現する位相が時間変化する。従って先ず、レチクル及び基板の走査方向が問題となる。次に一括露光方式のときに用いた振動ミラーを併用する場合、その走査方向並びにレチクル及び基板の走査速度に合わせて振動ミラーをどのように制御するかが問題になる。

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【0006】 例えば、図7(a)～(d)はスリット状の照明領域51に対してX方向（走査方向SR）にレチクルRを走査する状態を示し、図7(a)の状態から図7(d)の状態にかけて、次第にレチクルRのパターン領域PAが相対的に照明領域51により走査される。従って、レチクルRのパターン領域PAではX方向に対しては実質的に走査が行われているが、X方向に垂直なY方向（非走査方向）に対しては静止状態であるため、走査方向と非走査方向とでスペックルパターンの影響が異

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なっている。

【0007】本発明は斯かる点に鑑み、スリットスキャン露光方式の露光装置で空間コヒーレンスの高い光を露光光として使用する場合に、スペックルパターンによる照度むらをできるだけ小さくすることを目的とする。

【0008】

【課題を解決するための手段】本発明による第1の露光装置は、例えば図1及び図2に示すように、所定の空間コヒーレンスを有する照明光($L B_0$)を発生する光源(1)と、その照明光で所定形状の照明領域(15)を照明する照明光学系(2~14)と、照明領域(15)に対して相対的に転写用のパターンが形成されたマスク(R)及び感光性の基板(W)を同期して走査する相対走査手段(32, 34, 35, RST, WST)とを有し、マスク(R)のパターンを逐次基板(W)上に露光する露光装置において、照明光($L B_0$)の空間コヒーレンスの高い方向(方向H)を所定形状の照明領域(15)とマスク(R)との相対的な走査方向(方向SR)と同一にしたものである。

【0009】また、本発明による第2の露光装置は、例えば図1及び図2に示すように、所定の空間コヒーレンスを有するパルス光($L B_0$)を発生するパルス光源(1)と、そのパルス光で所定形状の照明領域(15)を照明する照明光学系(2~14)と、照明領域(15)に対して相対的に転写用のパターンが形成されたマスク(R)及び感光性の基板(W)を同期して走査する相対走査手段(32, 34, 35, RST, WST)とを有し、マスク(R)のパターンを逐次基板(W)上に露光する露光装置において、所定形状の照明領域(15)とマスク(R)との相対的な走査速度と、照明領域(15)でのそのパルス光のスペックルパターンのその相対的な走査方向(方向SR)のピッチとに応じて、照明領域(15)でのそのパルス光のスペックルパターンの位相をそのパルス光毎に変化させる位相可変手段(8, 9)を設けたものである。

【0010】この場合、そのパルス光の空間コヒーレンスを検出する空間コヒーレンス検出手段(17, 18)と、このように検出されたそのパルス光の空間コヒーレンスに応じて位相可変手段(8, 9)の動作を制御する制御手段(32)とを設けることが望ましい。

【0011】

【作用】斯かる本発明の第1の露光装置によれば、予め照明光($L B_0$)の光束に垂直な面内で空間コヒーレンス(可干渉性の程度)の高い方向を計測しておき、所定形状の照明領域(15)においてマスク(R)との相対的な走査の方向(SR方向)に、その空間コヒーレンスの高い方向を合わせている。従って、例えば図4に示すように、照明領域(15)上に形成される照明光によるスペックルパターンの走査方向(SR方向)の照度分布は、分布曲線40のように所定ピッチで比較的大きい振

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幅で変動する。また、その照明領域(15)上のスペックルパターンの非走査方向(Y方向)の照度分布は、分布曲線41のように比較的平坦である。この場合、走査方向ではマスク(R)上の各点の照度分布は、それぞれ分布曲線40のように変化して、実質的に振動ミラーで走査した場合と同様になるため、照度むらは少ない。また、非走査方向ではもともと照度むらは少ないため、マスク(R)及び基板(W)の全面で照度むらが少なくなる。

【0012】また、本発明の第2の露光装置によれば、照明光としてパルス光が使用されている。パルス光が例えば遠紫外域のエキシマレーザ光(波長が例えば248nm)である場合、光学系での色収差を消すことが容易ではないため、パルス光源(1)では回折格子及びスリット等を使用することによりスペクトル線幅を狭帯化したパルス光を発生する。そのため、図1において、光源(1)から射出されるパルス光($L B_0$)は、水平方向(H方向)で空間コヒーレンスが高く且つビーム幅が狭くなっているが、垂直方向(V方向)では空間コヒーレンスが低く且つビーム幅が広くなっている。従って、本発明では光源(1)から射出されるパルス光($L B_0$)の水平方向を、マスク(R)上のスリット状の照明領域(15)の走査方向に設定する。

【0013】この場合、そのパルス光($L B_0$)の水平方向の幅と垂直方向の幅との比は、一般に通常のスリット状の照明領域(15)の走査方向の幅と非走査方向の幅との比よりも小さいため、例えば図3に示すような、2枚のシリンドリカルレンズ38及び39を用いて、そのパルス光($L B_0$)の水平方向の幅を広げる必要がある。このとき、入射するパルス光($L B_0$)の拡がり角を θ_1 、前段のシリンドリカルレンズ38の焦点距離を f_1 、後段のシリンドリカルレンズ39の焦点距離を f_2 とすると、シリンドリカルレンズ39から射出されるパルス光(LB)の拡がり角 θ_2 は、次のようになる。

$$\theta_2 = (f_1 / f_2) \theta_1 \quad (1)$$

従って、水平方向のビーム幅を広げるために、 $f_1 < f_2$ とすると、次のようになり、射出されるパルス光(LB)の拡がり角 θ_2 は小さくなる。

$$\theta_1 > \theta_2 \quad (2)$$

従って、ビーム幅を水平方向に広げると、図4に示すように照明領域(15)の走査方向(SR方向)での空間コヒーレンスは更に高くなる。そのため、走査方向にはコントラストの高いスペックルパターンが形成される。これに対して非走査方向のスペックルパターンのコントラストは低いため、非走査方向では照度むらは少ない。

【0015】その照明領域(15)の走査方向の照度分布は例えば図5(a)の分布曲線40のようになる。マスク及び基板の走査方向をこの方向に選べば、走査による位相ずれによって図5(b)のように様々な位相の波の疊重になるので、積算効果によってスペックルの軽減

が見込まれる。但し、何等かの制御を行わない場合、走査速度によっては、パルス発光のタイミングとスペックルパターンの位相がほぼ一致する形になり、マスク (R) 上の或る照射点では、例えば図 5 (a) の位置 40 C, 40 F, …の順に露光が行われ、別の照射点では位置 40 B, 40 E, …の順に露光が行われて、積算効果が見込めず、照度むらが軽減されない可能性もある。これを避けるために、図 5 (a) の位置 40 C, 40 F, 40 I で、パルス発光が行われるような走査速度のときは、振動ミラーを走査させて、位置 40 F で発光するときは δA 、位置 40 I で発光するときは δB だけ横ずれさせるような走査制御をする。

【0016】これによりマスク (R) 上の各照射点は、図 5 (b) の分布曲線 40, 42, 43 という、パルス数に応じて等分されて、異なる位相のスペックルパターンをもつ照度で露光されるため、積算露光量は平均化され、マスク (R) 上の走査方向での照度むらは低減される。即ち、マスク (R) 上の任意の照射点において、 n, m を整数として、パルス発光毎に分布曲線 40 上の走査方向の位相が $0, 2m\pi + (2\pi/n), 4m\pi + (4\pi/n), 6m\pi + (6\pi/n), \dots, 2(n-1)m\pi + (n-1)\pi/n, \dots$ となるように、位相可変手段 (8, 9) の動作を制御することにより、走査方向の照度むらが低減される。

【0017】また、そのパルス光の空間コヒーレンスを検出する空間コヒーレンス検出手段 (17, 18) と、このように検出されたそのパルス光の空間コヒーレンスに応じて位相可変手段 (8, 9) の動作を制御する制御手段 (32) とを設けた場合には、検出された空間コヒーレンスに応じて、マスク (R) 及び基板 (W) 上でのスペックルパターンに起因する照度むらが最小になるように、位相可変手段 (8, 9) の動作を制御する。

【0018】

【実施例】以下、本発明による露光装置の一実施例につき図面を参照して説明する。本実施例は、露光光の光源としてパルス発振型のレーザ光源を使用したスリット式キャノン露光方式の投影露光装置に本発明を適用したものである。図 1 は本例の投影露光装置の光学系を示し、この図 1 において、エキシマレーザ光源 1 から射出された遠紫外域 (波長は例えば 248 nm) のレーザビーム L_{B0} は、紫外用反射ミラー M1, M2, M3 及び M4 を介してシリンドリカルレンズを含むビーム整形光学系 2 に入射する。エキシマレーザ光源 1 から射出されたレーザビーム L_{B0} の断面形状は、水平方向 (H 方向) の幅が垂直方向 (V 方向) の幅よりも狭い細長い矩形であり、ビーム整形光学系 2 では、レーザビーム L_{B0} の水平方向の幅を拡げ、後述のスリット状の照明領域 15 の縦横比とほぼ同じ縦横比の断面形状のレーザビーム L_B を射出する。

【0019】

図 3 は、ビーム整形光学系 2 の構成を示す。

し、この図 3 に示すように、入射するレーザビーム L_{B0} は、焦点距離 f_1 のシリンドリカルレンズ 38 及び焦点距離 f_2 ($f_2 > f_1$) のシリンドリカルレンズ 39 を経て、断面形状の水平方向の幅が f_2/f_1 倍に拡大される。入射するレーザビーム L_{B0} の拡がり角を θ_1 とすると、射出されるレーザビーム L_B の拡がり角 θ_2 は、拡がり角 θ_1 の f_1/f_2 に減少している。一般に、光束の空間コヒーレンスは拡がり角が小さい程高いため、射出されるレーザビーム L_B の水平方向 (H 方向) の空間コヒーレンスは、入射するレーザビーム L_{B0} よりも高められている。

【0020】図 1 に戻り、ビーム整形光学系 2 から射出されたレーザビーム L_B は、紫外用反射ミラー M5 で折り曲げられてビームエクスパンダー (又はズームレンズ) 3 に入射し、所定の断面寸法にまで断面形状が拡大される。ビームエクスパンダー 3 から射出された平行なレーザビーム L_B は、偏光手段としての水晶プリズム 4 に入射し、2 つの直交する偏光成分に分離される。このように分離された 2 つの偏光成分は、光路補正用の石英ガラスプリズム 5 に入射し、ビームの進行方向が補正される。その後、2 つの偏光成分のレーザビームは、1 段目のフライアイレンズ 6 及びリレーレンズ 7 を経て、振動ミラー 8 で折り曲げられる。振動ミラー 8 は駆動装置 9 により、水平面上の所定の角度範囲内でレーザビームを適切な制御方法で走査する。

【0021】振動ミラー 8 で走査されるレーザビームが、リレーレンズ 10 を経て 2 段目のフライアイレンズ 11 に入射し、その射出側の焦点面に多数の 3 次光源 (スポット光) が結像され、これら多数の 3 次光源からのレーザビームが、更に集光レンズ 12 によって集光されミラー 13 で曲り折げられて、メインコンデンサーレンズ 14 に入射する。多数の 3 次光源からのレーザビームはメインコンデンサーレンズ 14 によって、レチクル R 上の短辺方向の幅が D の長方形の照明領域 15 に重量して照射される。その照明領域 15 内のパターン像が投影光学系 PL を介してウエハ W 上の長方形の露光領域 16 内に結像投影される。

【0022】この場合、投影光学系 PL の光軸に平行に Z 軸を取り、その光軸に垂直な XY 平面内の X 軸を長方形の照明領域 15 の短辺方向に取る。そして、本例では、投影光学系 PL の投影倍率を β として、照明領域 15 に対してレチクル R を X 方向 (これを「走査方向 SR」とする) に速度 V で走査するのと同期して、ウエハ W を -X 方向 (これを「走査方向 SW」とする) に速度 $\beta \cdot V$ で走査することにより、レチクル R のパターン領域 PA 内の回路パターン像が逐次ウエハ W のショット領域に投影露光される。

【0023】図 1 において、エキシマレーザ光の空間コヒーレンスを調べるために、集光レンズ L 1 を紫外用反射ミラー M 5 の後ろに設置し、紫外用反射ミラー M 5 で

の漏れ光を集光レンズL 1の後側焦点位置に集光させ、その焦点位置に設置したCCDよりなる2次元撮像素子17で2次元的に分布する漏れ光を受光する。そして、2次元撮像素子17からの撮像信号を画像処理系18で処理することで、レーザビームの発散角を測定するようにした。レーザビームの発散角は空間コヒーレンスに対して反比例の関係にあるため、その測定した発散角により、照明領域15上での走査方向SR及び非走査方向の空間コヒーレンスを算出することができる。

【0024】図2は、図1の投影露光装置の制御系を示し、この図2において、エキシマレーザ光源1内には、レーザ発振の媒体となるガスや発振トリガ用の電極を封入したレーザチューブ21、共振器を構成する所定の反射率(100%未満)を持ったフロントミラー22、その共振器のリアミラー23、波長選択用の開口板29、波長選択及び波長狭帯化用のプリズム24、及び反射型回折格子25等が、光学素子として設けられている。更に、エキシマレーザ光源1には、レーザチューブ21内の電極に高電圧を印加して発振を行わせるための発振制御部26、発振されるレーザビームの絶対波長を常に一定にするために、回折格子25の傾斜角を調整する波長調整駆動部27、及びリアミラー23の傾きを調整するための駆動部28等が設けられている。

【0025】また、フロントミラー22から射出されたレーザビームの一部を、ビームスプリッター30を介して波長検出器(分光器等)3に導き、波長検出器31でレーザビームの波長を検出し、検出した波長を波長調整駆動部27に伝達する。波長調整駆動部27は、波長検出器31で検出された波長に応じて、予め定められた絶対波長との差が規格内になるように回折格子25の傾斜角を変化させる。また、2次元撮像素子17からの撮像信号を画像処理系18で処理して検知されるビーム発散角に応じた信号(具体的には、2次元撮像素子17上に作られたビームスポットの大きさに応じた信号)は、エキシマレーザ光源1のリアミラー23の駆動部28へフィードバックされると共に、装置全体の動作を制御する主制御装置32へも送られる。駆動部28は予め定められた値に対して実測されたビームの発散角の値が、許容範囲以上に外れているときは、リアミラー23の傾斜角を変化させる。

【0026】また、図1のレチクルRの位置決め及び走査は図2のレチクルステージRSTによって行われ、ウエハWの位置決め及び走査は図2のウエハステージWSTによって行われる。レチクルステージRSTは、1チップのパターンが描かれたレチクルRの照射範囲を順次変えるために、レチクルRの走査を行う。ウエハステージWSTは、ウエハW上の複数のショット領域の夫々に対してレチクルRのパターン像が露光されるように、X方向及びY方向にステップ・アンド・リピート方式でウエハWを移動させる機能と、レチクルRの照射範囲に応

じてレチクルRの走査に同期してウエハWを走査する機能とを合わせ持つ。

【0027】主制御装置32は、発振制御部26を介してエキシマレーザ光源1の発振を制御し、ウエハステージ制御系34及びレチクルステージ制御系35を介してそれぞれウエハステージWST及びレチクルステージRSTの動作を制御する。そして、主制御装置32は、駆動装置9を介して振動ミラー8の振動の振幅及び周期等を制御する。また、主制御装置32には、入力装置としてのキーボード36、座標入力装置(所謂マウス)37や出力装置としての表示部(CRTディスプレイ、メータ等)33等が接続されている。キーボード36及び座標入力装置37は、或るウエハの露光処理にあたって1ショット領域当り何パルスで露光するかを予め指定することの他に、種々のシーケンス設定やパラメータ設定のために使われる。

【0028】また、主制御装置32は、予備発振中のエキシマレーザ光源1からのレーザビームのビーム発散角の情報を画像処理系18から受け取り、スループットを下げないで、スペックルパターンを最も小さくするように最適化された発振周波数、及びウエハW上の1つのショット領域に照射されるレーザビームのパルス数を決定して、発振制御部26に指令を発する。並行して主制御装置32は、振動ミラー8の振動周期、振幅、及び位相を決定して駆動装置9に指令を発すると共に、レチクルステージ制御系35およびウエハステージ制御系34には、最適な走査速度を決定して指令を出す。

【0029】次に、本例でレチクルR及びウエハW上の照度むらを低減させるための構成について説明する。まず、本例では、図1においてエキシマレーザ光源1から射出されるレーザビームLB₀の空間コヒーレンスは水平方向(H方向)に高くなっている。そこで、そのレーザビームLB₀の空間コヒーレンスの高い方向が照明領域15の短辺方向、即ち走査方向SRになるように、照明光学系を構成する。これにより、レチクルR上の照明領域15上に形成されるレーザビームのスペックルパターンは、走査方向SRのコントラストが高く、非走査方向(Y方向)のコントラストが低くなっている。

【0030】図1のレチクルR上及びウエハW上に生成されるスペックルパターンには、フライアイレンズ6及び11のレンズエレメントの配列に対応した周期的な成分が含まれており、この干渉パターンのコントラストは、レチクルR上のX方向に高くなる。本例では、スペックルパターンのコントラストを低減させるために、レーザビームLBを、偏光手段としての水晶プリズム4により所定の角度をなす2つの偏光成分のレーザビームに分離してレチクルRを照明している。その2つの偏光成分の内の、第1の偏光成分のレーザビームによる照明領域15の走査方向(X方向)の照度分布I(X)(相対値)は、図6(a)の分布曲線40のように、所定ピッ

チで周期的に変化している。これに対して、第2の偏光成分のレーザビームによる照度分布 $I(X)$ は、分布曲線 4-4 で示すように分布曲線 4-0 に対して X 方向に半ピッチだけずれている。これにより全体の照度分布 $I(X)$ は、図 6 (b) の分布曲線 4-5 となり、照度分布の変動の振幅は低減される。

【0031】図 4 は本例のレチクル R 上の照明領域 1-5 の照度分布を示し、レチクル R 上には図 4 (a) に示すように走査方向 S R (X 方向) の幅 D の照明領域 1-5 が形成されている。そして、照明領域 1-5 の X 方向の照度分布 $I(X)$ は、図 4 (b) の分布曲線 4-0 のように所定ピッチで比較的大きな振幅で変化し、照明領域 1-5 の Y 方向の照度分布 $I(Y)$ は、図 4 (c) の分布曲線 4-1 のようにほぼ平坦である。従って、非走査方向である Y 方向での照度むらは小さくなっている。また、本例では、 X 方向での照度むらを、照明領域 1-5 に対するレチクル R の走査及び図 1 の振動ミラー 8 によるレーザビームの走査により解消する。

【0032】図 5 (a) は、その照明領域 1-5 での 1 パルス光当りの走査方向 (X 方向) の照度分布 $I(X)$ に対応する分布曲線 4-0 を示し、原点から X 座標が D までの領域が図 4 (a) の照明領域 1-5 の内部である。また、照明領域 1-5 に対してレチクル R が X 方向に走査されると、レチクル R 上の各照射点が図 5 (a) (図 5 (b) も同様) の X 軸に沿って移動していくものとする。

【0033】本例では、パルス発光が行われ、分布曲線 4-0 のピッチを PX 、1 パルスのエネルギー密度及びレジスト感度から求められる必要パルス数を n とするとき、 n 回のパルス発光で、 $0, PX/n, 2PX/n, \dots, (n-1)PX/n$ の各位置にピークを持つ分布曲線が得られるような走査速度 ($0, PX/n, 2PX/n, \dots, (n-1)PX/n$ の順にピークをもつ分布曲線が出現する必要はない。 n 回のパルス発光で、各々の位置にピークを持つ分布曲線が全て得られればよい。また、 n が充分に大きくて、ピッチ PX を $n/2, n/3, \dots$ 等分した位置にピークを持つ分布曲線が得られればよい場合もある。) が、予め決定されている速度 (照射領域 D を必要パルス数 n で割ってレーザーの発振周波数 f を掛けた値 $V = (D/n) f$) と一致する場合、図 1 の振動ミラー 8 を走査させるまでもなく、レチクル R 上及びウエハ W 上での照度むらは最も効率よく軽減される。

【0034】例えば、必要パルス数が 3 の場合には、1 パルス毎にレチクル R は X 方向に $D/3$ だけ移動する。従って、図 5 (a) に示すように、レチクル R 上の或る照射点 ($X=0$) では、間隔 $D/3$ の位置 $40A, 40E, 40I, \dots$ の順に露光が行われ、 X 方向の露光量分布を見ると、図 5 (b) の分布曲線 4-0, 4-2, 4-3 のパルスの重ね合わせとなるため、積算露光量の光量むら

は、極めて小さくなる。レチクル R が 1 パルス毎に移動する距離は、照明領域 1-5 の走査方向の幅 D の整数分の 1 に予め設定されている。

【0035】但し、レチクル R 及びウエハ W の走査速度は後述のようにウエハ W 上での適正露光量等により決定されるため、必ずしも前記の条件が満足されない場合がある。このような場合には、図 1 の振動ミラー 8 を走査して、 $0, PX/n, 2PX/n, \dots, (n-1)PX/n$ の位置にピークをもつ分布曲線が得られるようになる必要がある。

【0036】具体的に必要パルス数が 4 の場合には、1 パルス毎にレチクル R は、 X 方向に $D/4$ だけ移動する。従って、図 5 (a) に示すようにレチクル R 上の或る照射点 ($X=0$) では、間隔が $D/4$ の位置 $40A, 40D, 40G, 40K, \dots$ の順に露光が行われ、別の或る点、 $X=0$ の位置から $D/6$ だけ離れた点では、位置 $40C, 40F, 40I, 40L$ の順に露光が行われるため、 X 方向の積算露光量の分布は、分布曲線 4-0 の重ね合わせとなり、光量むらの軽減は全くされない。そこで振動ミラー 8 を走査させる。例えば、位置 $40F$ での露光のときは $PX/4$ 、位置 $40I$ のときは $PX/2$ 、位置 $40L$ のときは $3PX/4$ だけ振動ミラー 8 の走査によって位相を変えると、図 5 (c) のように異なる 4 種類の位相の波の重疊となり、照度むらが極めて小さくなる。図 5 (c) で、分布曲線 4-6, 4-7, 4-8 は、分布曲線 4-0 から振動ミラー 8 によってそれぞれ位相を $PX/4, PX/2, 3PX/4$ だけ変えたものである。

【0037】次に、レチクル R 及びウエハ W の走査速度について説明する。先ずウエハ W の走査速度は、ウエハ W に与える適正露光量 (これはウエハ W 上に塗布されているレジストの感度により定まる) と、パルス毎のエネルギー量とによって決定される。エキシマレーザ光源 1 のような光源の場合、パルス毎に放出されるエネルギー量が異なるので、照明光学系の中で減光して、パルス数を増やして露光することによって、その積算効果でウエハ W に与える露光量のばらつきが少なくなるように、パルス毎のエネルギー量は決定される。

【0038】ウエハに与える適正露光量を E 、パルス毎のエネルギー量 (平均エネルギー量) を E_r とすると、露光パルス数は E/E_r で表され、レチクル R 上で一度に照明される範囲の走査方向の長さ (即ち照明領域 1-5 の走査方向の幅) は D であるため、1 パルス毎のレチクル R の移動量は $(E_r/E) D$ となり、エキシマレーザ光源 1 の発振周波数が f [Hz] のとき、レチクル R の走査速度 V は、次式の値に設定される。

$$V = (E_r/E) f \cdot D \quad (3)$$

なお、上述実施例では照明領域 1-5 の非走査方向 (図 4 の Y 方向) へのスペックルパターンの走査は行っていないかったが、非走査方向の照度むらをより軽減するために

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は、例えば図1において振動ミラー8を垂直方向へ振ることにより、非走査方向へもスペックルパターンの走査を行うことが望ましい。

【0040】また、図4において、走査方向SR(X方向)と非走査方向(Y方向)との両方にスペックルパターンを振動させるためには、X方向とY方向とに交差する方向にスペックルパターンを振動させても良い。

【0041】なお、空間コヒーレンスが高い方向とスキャン方向とを一致させる方法には次のような手法もある。

①露光装置本体側でレチクル、ウエハをX、Y両方向にスキャン可能に構成しておけば、本体とレーザ光源とを接続させた後であっても、コヒーレンスが高い方向をスキャン方向とするだけでよい。このとき、この決定されたスキャン方向がレチクル上の照明領域の短手方向となるように、例えばレチクルブラインドで照明領域の形状を設定する必要がある。

②レーザ光源からのレーザ光の空間コヒーレンスの高い方向が、スキャン方向と一致するように露光装置の照明光学系に入射するレーザビームのコヒーレンスの高い方向を、例えば複数枚のミラーによって調整すれば良い。但しフライアイレンズ等の調整を行う必要があることもある。一般的にはコヒーレンスの高い方向を考慮して装置を組むことが望ましい。

【0042】なお、本発明は上述実施例に限定されず、例えば露光光としてYAGレーザーの高調波よりもレーザ光を用いる場合や、露光光として水銀ランプの1線のような連続光を使用する場合など、本発明の要旨を逸脱しない範囲で種々の構成を取り得ることは勿論である。

【0043】

【発明の効果】本発明の第1の露光装置によれば、スペックルパターンの干渉縞のコントラストの高い方向が走査方向に一致し、その走査方向の照度むらは照明領域とマスク(基板)との相対的な走査で軽減されるため、スペックルパターンによる照度むらが小さくなる利点がある。

【0044】また、第2の露光装置によれば、照明領域とマスクとの相対的な走査速度と、その照明領域でのパルス光のスペックルパターンの相対的な走査方向のピッ

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チとに応じて、照明領域でのパルス光のスペックルパターンの位相をパルス光毎に変化させることができるために、スペックルパターンによる照度むらを小さくできる利点がある。

【0045】また、パルス光の空間コヒーレンスを検出する空間コヒーレンス検出手段と、このように検出されたパルス光の空間コヒーレンスに応じて位相可変手段の動作を制御する制御手段とを設けた場合には、特にスペックルパターンによる照度むらを小さくできる。

【図面の簡単な説明】

【図1】本発明の一実施例の投影露光装置を示す斜視図である。

【図2】実施例の投影露光装置の制御系を示すブロック図である。

【図3】図1のビーム整形光学系2の一例を示す構成図である。

【図4】レチクルR上の照明領域15の照度分布を示す斜視図である。

【図5】(a)はレチクルR上の照明領域15の走査方向の照度分布を示す図、(b)及び(c)はそれぞれスペックルパターンを振動させる場合の照明領域15の走査方向の照度分布を示す図である。

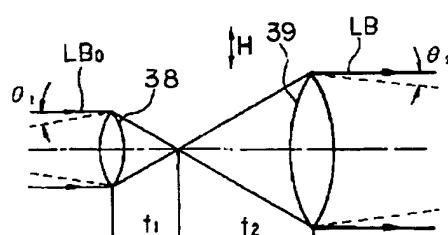
【図6】(a)は2方向からのレーザビームで照明領域15を照明する場合の照明領域15の2つの照度分布を示す図、(b)は図6(a)の2つの照度分布の和の照度分布を示す図である。

【図7】スリット状の照明領域に対するレチクルの走査の様子を示す図である。

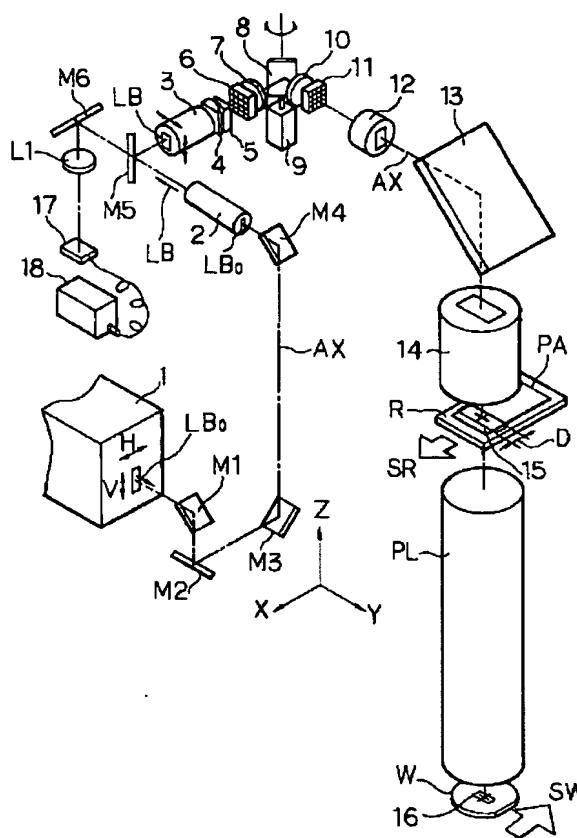
【符号の説明】

- 30 1 エキシマレーザ光源
- 6, 7 フライアイレンズ
- 8 振動ミラー
- 15 照明領域
- 17 2次元撮像素子
- 18 画像処理系
- R レチクル
- PL 投影光学系
- W ウエハ
- RST レチクルステージ
- 40 WST ウエハステージ

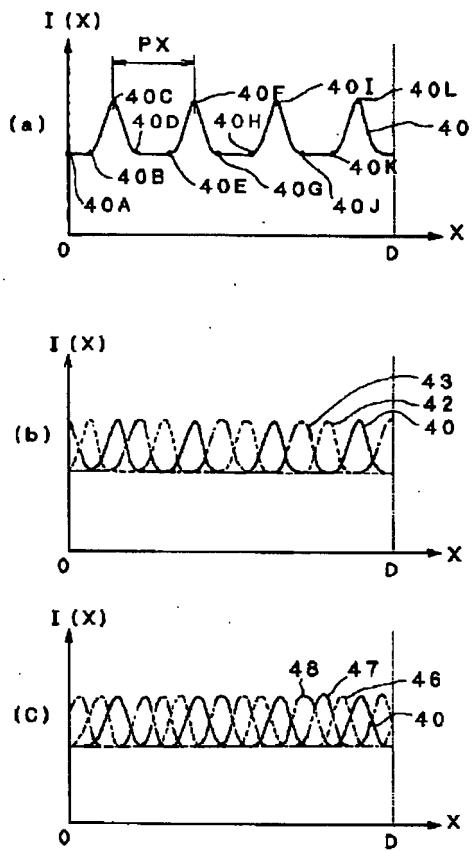
【図3】



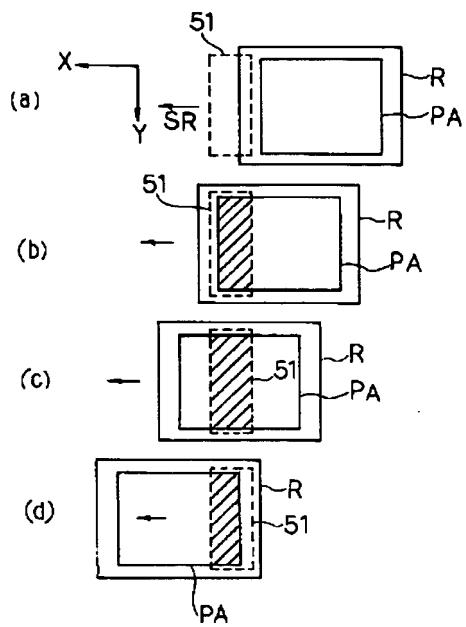
【図1】



【図5】



【図7】



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